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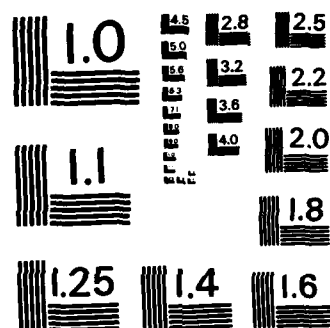
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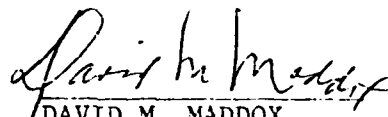
ANALYTIC SUPPORT OF THE FORCE DESIGN PROCESS

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## ABSTRACT

This report documents a research effort conducted by the Force Design Analysis Division, Studies and Analysis Directorate, CAORA to examine the "front-end" force design process executed by Force Design Directorate, CACDA. Research resulted in a description of the force design process, identification of steps in the process requiring analytic support and proposed methodologies to execute comparative analysis of alternative force designs.

## EXECUTIVE SUMMARY

1. Introduction. Recent force design actions executed by Force Design Directorate, CACDA have been accomplished in a much shorter time frame than previous actions. In the case of the Army of Excellence Study- (Aug - Nov. 83), the time span of the initial force design process was less than twelve weeks. The analytic methodologies previously employed by the Force Design Analysis Division were not adaptable to such short term requirements.

2. Purpose. A research project was executed during the period February-May 1984 to investigate the "short term" CACDA force design process. The purpose of the project was to define the design process, identify steps in the process which require analytic support, describe methodologies to provide responsive analysis and identify available tools to perform "front-end" analysis.

3. Methodology. The methodology to execute this project included a literature search to examine underlying theory and previous similar efforts, meetings with FDD representatives to define the "short-term" force design process and consultation with CAORA analysts to reflect their experience in proposed methodologies. These actions led to the development of specific proposals to achieve a responsive capability for "front-end" force design analysis.

4. Analysis. In the initial phases of the Force Design Sequence, FDAD analysts provide input to FDD, CACDA based on results of relevant studies and gaming. The shortened time line does not allow for detailed gaming to generate force design alternatives and perform subsystem tradeoff analysis. The principal contribution which FDAD may make is to provide quantitative analysis of the alternative force designs generated by FDD, CACDA. Theoretical and practical approaches to this problem consistently divide force effectiveness analysis into the dimensions of deployability, lethality/survivability, sustainability, tactical mobility and C<sup>3</sup>I.

5. Findings. Investigation of methodologies and tools available to execute multi-dimensional analysis of force design alternatives resulted in the following findings for each dimension:

a. Deployability. FDD, CACDA currently possesses an adequate capability to generate estimates of force deployability in the dimensions of time and sorties. The tool employed to perform this analysis is the Automated Air Load Planning System (AALPS).

b. Lethality/Survivability. FDAD does not currently possess a responsive capability to perform "front-end" lethality/survivability analysis.

c. Sustainability. FDAD/LOGCEN does not currently possess a responsive capability to perform "front-end" sustainability analysis.

d. Tactical Mobility. Further research is required to clarify the importance and quantification of this dimension of force effectiveness. The extreme dependency of this dimension on mission, scenario and operational concept may necessitate a case-by-case approach.



e. C<sup>3</sup>I. Current C<sup>2</sup>AD research may provide a knowledge and model base to execute responsive analysis of alternative force designs. A capability to perform responsive analysis of C<sup>3</sup>I does not appear to exist within CAORA at present.

6. Recommendation. If a capability to perform "front-end" analysis is identified as a priority requirement, the following actions are recommended:

a. Deployability. FDAD analysts should work with FDD, CACDA to enhance deployability analysis to include other deployment assets.

b. Lethality/Survivability. FDAD should acquire a responsive model to perform lethality/survivability analysis of alternative force designs. A candidate model (counterforce potential) is recommended based on this research effort.

c. Sustainability. FDAD and FDD, CACDA should execute coordination with LOGCEN to develop and maintain a capability to perform sustainability analysis.

d. Tactical Mobility and C<sup>3</sup>I. MQA, FDAD and C<sup>2</sup>AD should execute additional research to develop a CAORA capability to perform responsive analysis of tactical mobility and C<sup>3</sup>I.

## 1. INTRODUCTION.

a. PURPOSE. A study of the CACDA Force Design Process was initiated in February, 1984 in the Force Design Analysis Division, Studies and Analysis Directorate, CAORA to examine the current Force Design Process (FDP) executed by the Force Design Directorate, CACDA. The purpose of this study is to define the "short term" FDP and to identify and examine specific steps in the process which may be supported analytically by FDAD. The Research Directive for this project is contained at APPENDIX A.

### b. BACKGROUND.

(1) Recent force design actions executed by FDD, CACDA have been performed in a much shorter time frame than previous actions. In the case of the Army of Excellence Study (Aug - Nov 83), the time span of the initial force design process was less than twelve weeks. The analytic methodologies and procedures employed by FDAD for programmed studies were not adaptable to such short term analysis. The time required to perform analysis utilizing current interactive simulations exceeds the time available in the short term force design process. Use of data from previous analysis efforts appears to be inappropriate due to changes in tactics, threat, operational environment and combat systems.

(2) The Army of Excellence Study demonstrated the need for analytic techniques in FDAD which may be of lower resolution but are more responsive to FDD, CACDA requirements for front-end analysis.

### c. REPORT ORGANIZATION.

(1) The following sections of this report document an effort to develop analytic techniques to support the "short term" force design process. Section 2 documents problem definition which resulted from research of recent study efforts. Section 3 provides a brief description of the FDD, CACDA force design process. Section 4 identifies steps in the design process which may require analytic support. Section 5 documents a theory and supporting methodology for comparative analysis of alternative force designs generated by CACDA.

(2) Due to the time constraints of this research action priority of effort was placed on methodology development to perform comparative analysis of alternative force designs. Section 6 presents the conclusions and recommendations of this research effort.

d. UTILITY. While the principal purpose of this research effort was to develop analytic methodologies, the effort also resulted in identification of key literature which should be studied by interns or analysts assigned to the Force Design Analysis Division. The principal recommended reading list is contained at APPENDIX B.

## 2. PROBLEM DEFINITION.

### a. Introduction.

(1) (U) The Division 86 Final Report, Oct 81, documents the force design effort which began with the Division Restructuring Study (circa 1976) and was concluded with the Chief of Staff of the Army's approval of the Division 86 structure on 1 August 1980. (Ref 1) This major redesign required some four years from concept to objective force design. Analytic support for this restructuring included field experiments, interactive wargames and simulations.

(2) In stark contrast, the "Army of Excellence" objective designs for the Infantry Division (Light) and the Heavy Division were completed in less than twelve weeks (30 Aug 83 - 10 Nov 83). (Ref 2) Analytic support for the "Army of Excellence" was restricted to "gamer insights", qualitative judgment and static measures of force effectiveness (WEI/WUV). It is clear that the timeline for force design had changed. While this condition may not occur frequently, it appears that a requirement exists to maintain a capability in CAORA to perform analysis to respond to "short term" force design questions.

b. PROBLEM STATEMENT. Given the shortened timeline for force design, what techniques are available to provide quantitative input to the design process to improve design quality and alternative analysis?

c. METHODOLOGY. In order to answer this question, the following objectives were established:

(1) Define the "shortened time horizon" force design process.

(2) Identify specific steps in the process which may require analytic support from FOAD.

(3) For each step, develop an appropriate methodology for quantitative analysis.

(4) Present proposed methodologies to gain acceptance and implementation.

(5) Implicit in this research process was the requirement for a literature search to identify supporting theory, existing procedures and analytic techniques relating to the force design process. The literature search included examination of recent front-end analytic efforts performed by CAORA.

d. LITERATURE SEARCH. A continuous review of literature was performed during this research effort. Frequently, formulation of a methodology or review of a previous study led to examination of a referenced publication. While the key reference materials used in this study are shown at APPENDIX B., several will be highlighted in the following subparagraphs to clarify the problem context.

(1) DA, TRADOC Briefing. "Force Structure and Design Initiatives for an Army of Excellence", Nov 83. This briefing packet provides an overview of the concepts and methodology which led to the AOE proposed force designs. The key dimensions of quantitative comparison of alternative force designs presented in this briefing were deployability and "foxhole strength". (Ref 3)

(2) Tiede, Roland V. On the Analysis of Ground Combat. 1978. Roland Tiede documents a theory of ground combat based upon twenty-five years of experience as a professional soldier and fourteen additional years as a civilian practitioner of military operations research. Of particular value is Tiede's analytic partitioning of the combat functions of a military force into application of firepower, movement of firepower, service support, sensing and countersensing and combat management. Tiede also clarifies the role of modeling in force design. (Ref 4)

(3) TR 4-78. CACDA Ground Combat Model. TR 4-78 documents a quick-running, low-resolution battalion-level simulation model to perform screening of force design alternatives. The model was used to support the MANFIST Study. (Ref 5)

(4) CAA-TP-73-7. Firepower Potential Methodology Review. This publication documents the development of a methodology for quantification of individual weapon system contribution to force effectiveness. This publication provides an example of a static measure of effectiveness dependent on weapon system performance characteristics. (Ref 6)

(5) TR 4-80 (C) Screening Exercises in Support of ID-86 (U) Documents a methodology employed by CAORA (CASAA) to perform static analysis/screening of alternative force designs in the dimensions of deployability, lethality, survivability, tactical mobility and cost. Several models were employed to perform the analysis of alternatives in a short time period. Lethality and survivability relied on static measures of weapon system performance characteristics. (Ref. 7)

(6) SPC Report 866. Counterforce Potentials User's Manual. Dec 82. This report documents a model and methodology developed by System Planning Corporation for analysts in the Office of the Secretary of Defense. Of the models examined, this appears to be the best approach for front-end analysis of alternative force designs in the dimensions of lethality and vulnerability. (Ref. 8)

### 3. CACDA FORCE DESIGN PROCESS.

a. GENERAL. The force design process examined in this chapter is based on the general sequence of events which led to the initial designs for an "Army of Excellence". FDD, CACDA is currently documenting the AOE effort in detail. This chapter presents a general process model to enable identification of steps in the process which might be supported by analysis. Figure 3.1 provides a flow chart of the FDD Force Design Sequence. This sequence is a general description of the process followed for the "Army of Excellence" initial design effort. Rectangles in the figure represent processes, circles/ovals represent the products of a preceding process and diamonds indicate a decision point. While the figure presents a sequential process, some activities might occur simultaneously. The following paragraphs clarify the components of the force design sequence.

b. TASKING FROM TRADOC/DA. Guidance and requirements are furnished to CAC from TRADOC/DA. This tasking includes dates for interim and final reports, general guidance, points of contact, relationship of specific task to overall force design and specific directions as appropriate. In the case of the AOE effort, the DA tasking identified personnel constraints and sortie limitations for the Light Infantry Division.

c. PROBLEM DEFINITION. The TRADOC/DA tasking is translated into specific design goals for specific situations. Situations are characterized by force mission, enemy threat and environment. A "best" force must be designed within personnel, deployability or other constraints to accomplish a specific operational mission against a specified enemy threat in a specific geographic environment. The design problem is further complicated as the force should be designed for utility against other threats in other environments as well. The approach of utility across several threats and environments provides variety to operational planners but clearly increases the complexity of the design effort.

d. CONSTRAINED PROBLEM DEFINITION. The general tasking and guidance from DA/TRADOC is converted into specific goals for designs of Corps and Division level forces. In the case of the AOE, key constraints were personnel, deployability and direct combat strength. These constraints provide a basis for redesign and tradeoff examinations of the functional subsystems of the Corps and Divisions in the U.S. Army Force Structure.

e. DEVELOP METHODOLOGY. Dependent upon time, recent related design efforts, model availability etc. a detailed methodology for problem solution is developed. The methodology includes tasking of schools and centers, development of a detailed time schedule and tasking of supporting analytic agencies (CAORA, TRASANA, CIVILIAN CONTRACTORS). In terms of analysis, the front-end design sequence is time constrained and seeks as much as possible to apply results of recent related studies to the new design requirement. FDD analysts may provide input concerning relevant and responsive models available to support the design effort.

f. STUDY PLAN. The study/design plan is generated as a methodology is developed. The study plan identifies major tasks to be completed and the agencies which will execute those tasks. Task completion is related to the time line to clarify terms of reference for the action agencies.

g. DEVELOP DETAILED GUIDANCE AND TASKINGS. Using the FDD Study Plan as a basis, action officers in FDD develop and coordinate detailed tasking and guidance with the proponent schools and centers. Much of this action may be telephonic as in the case of the AOE design action.

h. DETAILED GUIDANCE/TASKING. FDD transmits guidance and taskings for input to the proponent schools and centers. Supporting analysis is also tasked at this point. In some cases, the analysis tasking may constitute a "warning order" pending input from the schools and centers. Analysis may be improved/facilitated by review of recent related studies while awaiting input from schools and centers.

# FDD FORCE DESIGN SEQUENCE

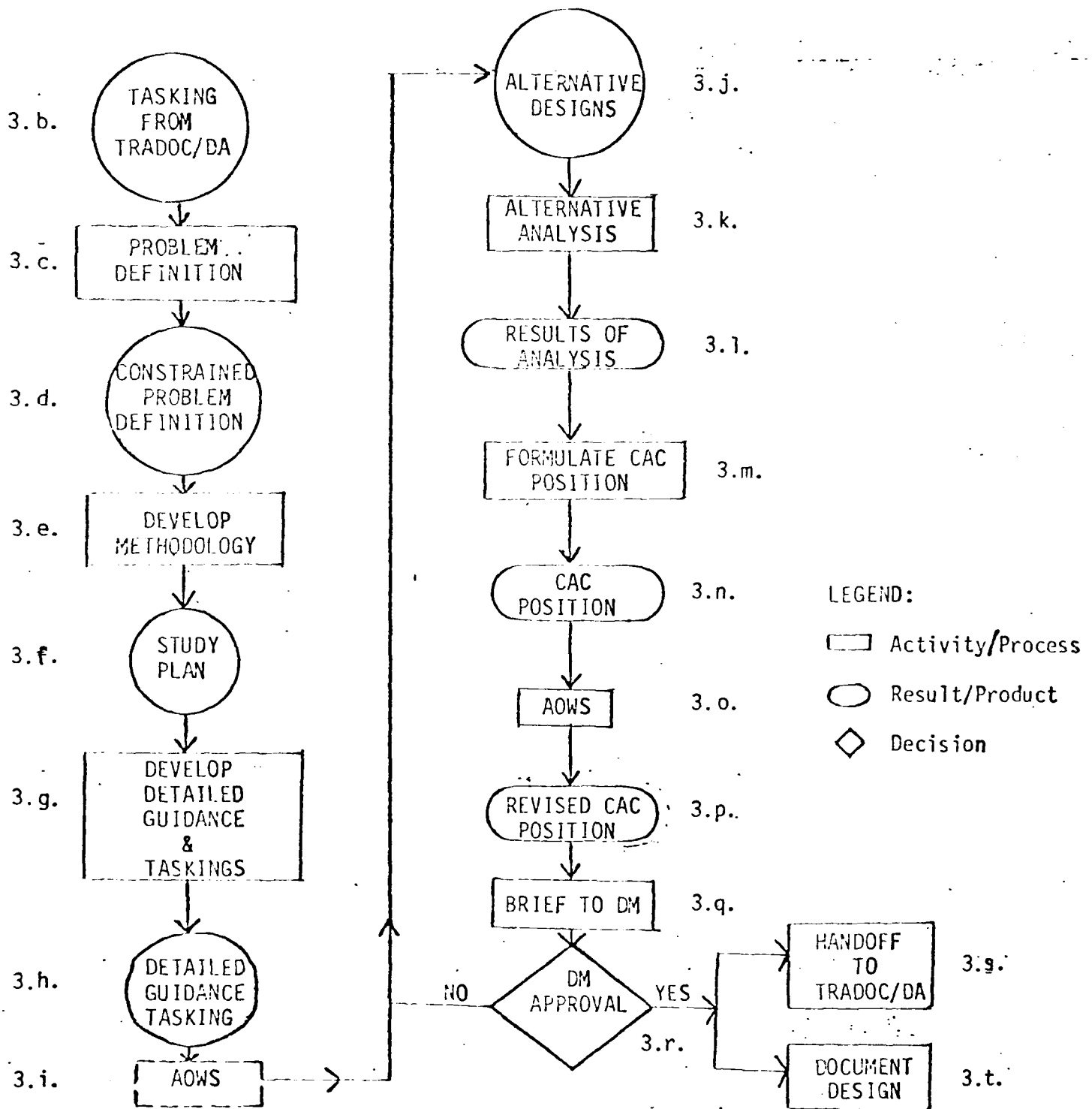


Figure 1. FDD Force Design Sequence

i. ACTION OFFICER WORKSHOPS (AOWS). Action Officer Workshops are convened at the appropriate integrating centers (CAC, LOGCEN, Soldier Support Center) to resolve conflicts in the force design effort. These workshops provide a forum for prioritization of needs and opportunity for tradeoffs to achieve the design goal. In recent design efforts, the key design goal/constraint has been personnel strength.

j. ALTERNATIVE DESIGNS. The AOWS effort results in several force design alternatives. These alternatives may be supplemented by inputs from MACOMs (FORSCOM, USAREUR etc) to arrive at a completed set of alternatives for comparative analysis. Force designs, at this point, consist of a rough Table of Organization and Equipment and an operational concept for force employment.

k. ALTERNATIVE ANALYSIS. A comparative analysis of force design alternatives is executed. Analysis is a combination of qualitative and quantitative evaluation of the relative strengths and weaknesses of each alternative. The analysis may result in some limited adjustment of the designs. Analysis may include static measures of force effectiveness (WEI/WUV) or may present relevant results of recent studies to attempt to quantify alternatives based on dynamic modeling.

l. RESULTS OF ANALYSIS. Comparison of alternatives may at least generate a table of rankings of alternatives across the dimensions of force effectiveness (deployability, lethality, survivability, tactical mobility, sustainability, C<sup>3</sup>I, cost). If possible the measures should be placed on an appropriate scale (ordinal, interval, ratio) so that magnitudes of difference may be compared (e.g. Deployability - 500 sorties vs 1000 sorties).

m. FORMULATE CAC POSITION. The analysis and evaluation of alternatives is briefed to the Commander, Combined Arms Center. Commander, CAC directs adjustments to the alternatives or additional analysis to arrive at CAC's proposed objective design.

n. CAC POSITION. The CAC proposal at this point is an objective force design which identifies personnel and major equipment allocation for the force by functional subsystems.

o. AOWS. An AOWS is conducted to resolve issues raised by the schools and centers concerning the CAC Position. Adjustments may be made to the CAC Position as a result of this meeting.

p. REVISED CAC POSITION. The result of the AOWS and Commander, CAC review is a revised CAC Position on a proposed force design. This design to include supporting analysis is prepared for decision briefing to TRADOC/DA.

q. BRIEF TO DECISION MAKER. The CAC position is briefed to appropriate decision makers at TRADOC and DA. A critical portion of this briefing is the presentation of analysis in a straightforward and precise manner. Comparative graphics which capture results appear to be the most effective means of conveying this information.

r. DECISION MAKER APPROVAL. The decision maker's approval is the basis for subsequent actions. Guidance may include adjustments to the design or requirements for additional analysis. The sequence is repeated to achieve final approval of the initial design.

s. HANDOFF TO TRADOC/DA. In some cases, the TRADOC or DA-Staffs may assume responsibility for higher level approval action of the proposed force design. Coordination between CAC and TRADOC/DA staff action officers will continue if this occurs.

t. DOCUMENT DESIGN. Upon approval, the force design is passed to FDD, Documentation Division for action. Action officers in FDD compile a report which explains the design effort for use in future design iterations. The AOE Final Report is currently in draft form and is an example of the process described in the above paragraphs.

#### 4. ANALYTIC SUPPORT OF THE FDP.

a. GENERAL. Section 3 provided a brief description of the "short-term" force design sequence based on the recent AOE design effort. This Section examines specific steps in the sequence which may require FDAD analytic support. Currently, the tools available to FDAD for rapid analysis are severely limited. Response times for analysis utilizing the Division Map Exercise (DIME) or JIFFY generally exceed time and resources available to execute front-end analysis. Previously accepted techniques for static comparison of forces using Fire Power Scores or WEI/WUV have limited utility. It appears that FDAD capabilities must be expanded to provide "front-end" analytic support. Specific proposals to achieve this capability are discussed in Section 5.

b. INITIAL ACTIONS. Capability for "front-end" analysis requires FDAD to perform routine actions before a specific analysis tasking is received. Key actions are identified in the following subparagraphs.

(1) Execute frequent coordination with FDD, Plans Division to identify upcoming analysis requirements and to advise FDD of FDAD analytic tools/resources available.

(2) Develop and maintain "front-end" analytic tools and data bases described in Section 5. This maintenance includes training of analysts to operate tools.

(3) Update tools and data bases for new weapon systems/munitions.

(4) Coordinate with analysts at other integrating centers concerning their portions of "front-end" analysis.

(5) Review recent studies to insure that relevant findings or considerations are included in "front-end" analysis. Awareness of content of previous studies may provide valuable insights relevant to new analytic taskings.



c. PROBLEM DEFINITION. Upon receipt of tasking, an FDAD analyst should be identified to work in a liaison capacity with FDD. The liaison analyst should be the Project Leader and assist in or at least observe the problem definition process. FDAD inclusion in problem definition is important to ensure that the supporting analysis depends on the common assumptions generated during this process. A reading/working notes file should be established to document verbal and written guidance provided by FDD which pertains to the specific design effort. These notes constitute a continuity file and an historical record for use in documentation of the analytic effort.

d. METHODOLOGY DEVELOPMENT. The FDAD analyst may provide information and assistance to FDD during this process. This step in the process is similar to designing an experiment to determine levels of examination and techniques of measurement. The timeline for execution generated at this point provides a basis for recommended models which the analyst may employ to assist in problem solution. The methodology development should include a general specification of the threats and environments to be investigated during alternative analysis. While proponent schools and centers perform these tasks to generate proposed force designs, the analytic group updates data for supporting models and investigates potential scenarios for force employment against the specified threat. This analysis (MAPEX) will aid in definition of the combat environment and type of combat engagements to be expected. In terms of CSS, the MAPEX may provide insights concerning supply route distances and capacities.

e. ALTERNATIVE ANALYSIS. The analytic efforts executed thus far in the process lead logically to a rapid analysis of force alternatives against a specific threat in a specific environment. This appears to be the process which may be best supported by quantitative analysis. The following section proposes specific techniques to perform comparative analysis of the alternative force designs.

## 5. COMPARATIVE ANALYSIS OF ALTERNATIVES.

a. INTRODUCTION. This section outlines a responsive methodology to execute comparative analysis of alternative force designs. This methodology is designed to provide quantitative support to the Force Design Directorate, CACDA. The methodology provides a quantitative basis for development of the CAC position on the force design in question.

(1) The fundamental question which this methodology seeks to answer is: "For a specified threat, environment and operational mission, which force design is most effective?"

(2) Theoretical literature and recent studies appear to be consistent in the analysis of force effectiveness by combat functions (DARCOM PAM 706-101, TIEDE, HTLD Study). The most common dimensions of comparative analysis of competing forces are listed below with proposed definitions for use in this methodology.

(a) Strategic Deployability - the ability to transport a force from a peacetime location to the tactical theater of operations.

(b) Lethality - the ability of a force to inflict casualties and damage on elements of the enemy force.

(c) Survivability - the ability of a force to withstand the effects of enemy or environmental actions which would otherwise result in loss of capability (DARCOM PAM 706-102).

(d) C<sup>3</sup>I - the ability of a force to sense, transmit information, plan, direct and control subordinate units as it executes a combat mission.

(e) Tactical Mobility - the ability of the force to reposition combat elements on the battlefield.

(f) Sustainability - the ability of the force to replenish units in a tactical environment.

b. ASSUMPTIONS. The following assumptions impact on the methodology presented in this chapter:

(1) Schools, Centers and CAC will generate alternative force designs which specify types and quantities of combat systems and personnel for each force. CAC will provide an operational concept for the tactical employment of each force.

(2) CAC will develop a threat force which specifies the type and quantities of enemy combat systems which will oppose the friendly force alternatives. CAC will further specify an operational concept for the threat force.

(3) Time and other resource constraints preclude execution of a high resolution combat model to generate combat results. Detailed modeling may be performed as a subsequent phase of the force design process to examine interactive effects as well as to refine organizational design and tactical employment.

(4) Data reflecting combat system physical and performance characteristics will be available for friendly and enemy systems. Data will be of the type presented in (S) TR 12-82, CAORA EUROPE V. SCENARIO CLASSIFIED DATA (U).

(5) Environmental (terrain and weather) effects will be characterized for the specific scenario to enable appropriate use of data.

c. THE IDEAL FORCE DESIGN MODEL. Figure 2 describes an idealized version of the use of combat models to improve force design. The ideal force design model would include a realistic representation of all subsystems of the force (Close Combat, C<sup>2</sup>, Fire Support, Air Defense, IEW, Communication, Combat Support, CSS, Aviation), their interactions and the result of combat against a specified threat in a particular environment. Such a model would not only assist in comparison of alternative force designs but could also assist in the execution of tradeoff analysis within a specific force design to approach an optimal design. The ideal model would require minimal time for "set up" and

running so that many alternatives could be examined in detail. The ideal force design model does not currently exist. The hierarchy of models (AMIP), standardization of data bases, scenarios, etc. appear to be efforts to achieve this goal. However, in the context of time constrained "front-end" analysis, it does not appear that such models will be responsive to the decision process. The approach proposed in the following sections seeks to accomplish quantitative analysis based on available tools, techniques and procedures which can meet the constraints of "front-end" force design.

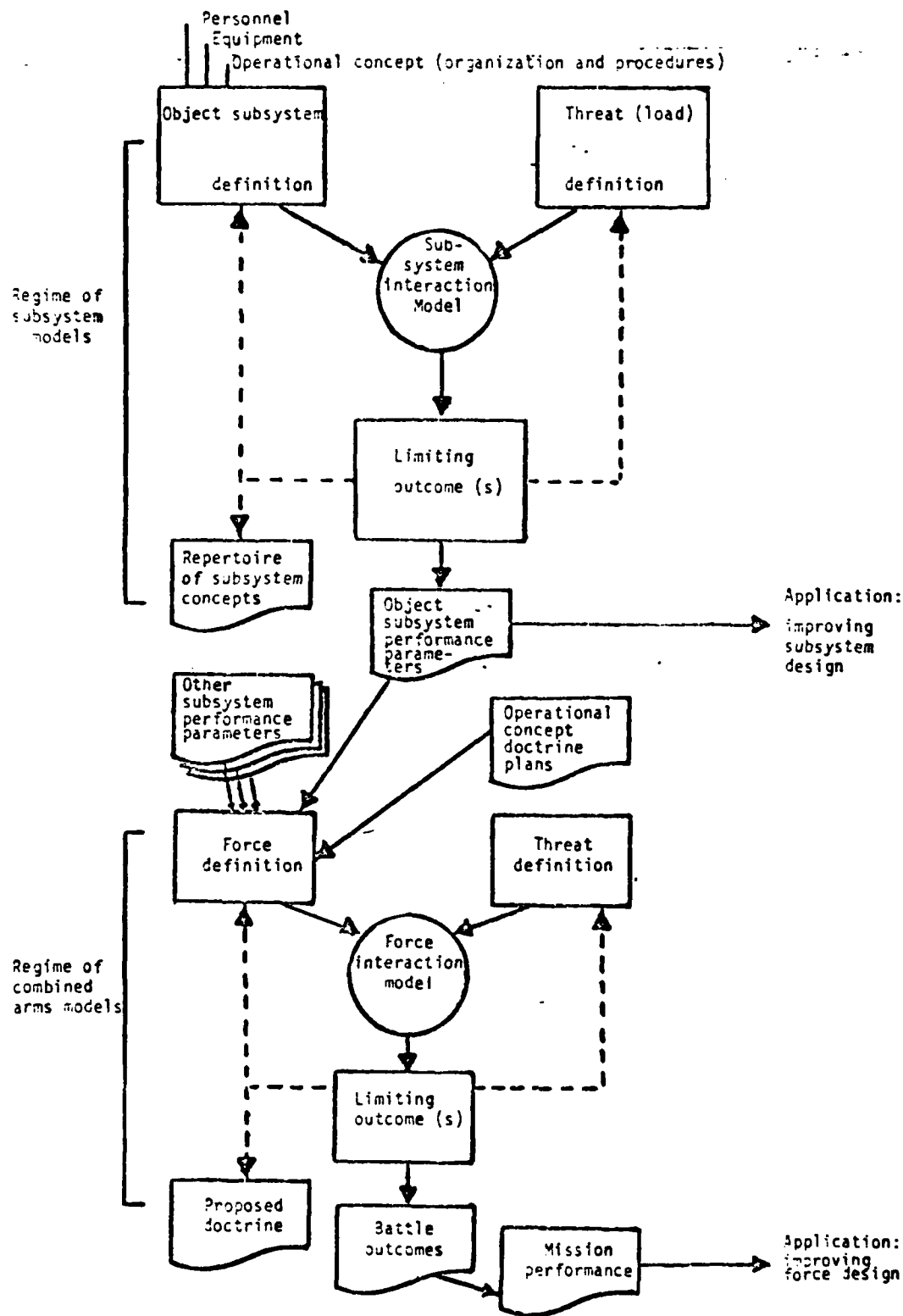


Figure 2. Use of Combat Models in Force Design  
(Ref 4, p. 151)

d. METHODOLOGY. Based on the above assumptions, the approach outlined in the following sections seeks to investigate the proposition that there is no significant difference between the force design alternatives generated by FDD, CACDA. Each alternative will be quantitatively characterized in terms of strategic deployability, lethality, survivability, sustainability, tactical mobility, and C<sup>3</sup>I. This quantification may then be used to investigate dominance or order preference of alternatives based on the decision maker's criteria. The following sections examine each dimension of comparative analysis to propose a method for quantification of alternatives.

e. STRATEGIC DEPLOYABILITY. A comparison of strategic deployability of force alternatives seeks to quantify time and resources (aircraft sorties and/or ships) required to move competing forces from base installations to the theater of tactical operations. This dimension is dependent on the scenario to determine constraints of sorties per day, mobilization time, and other transport constraints to include departure and arrival airfield operating characteristics. For prepositioned forces, deployability may not even be a relevant dimension for comparison of force alternatives. However, in relevant cases, strategic deployability can be quantified and may be a basis for comparison of force design alternatives.

(1) The analysis tool currently in use to perform deployability analysis is the Automated Air Load Planning System (AALPS). Based on TO&E's and aircraft characteristics, the number of sorties required to deploy a specific force design is obtained. Dependent on scenario and mission, the deployment sorties required can be converted into a force deployment schedule which quantifies the number of days required to deploy the force to the tactical theater of operations.

(2) The deployability analysis utilizing AALPS is currently performed by FDD, CACDA. The quantification of deployability was presented in the AOE design effort primarily in terms of total C-141 sorties required for force deployment. A secondary expression was in terms of days required to deploy a specific force. Total sorties required appears to be the best single descriptor of comparative deployability of force design alternatives. However, when several different modes of transportation are employed to deploy a force, days for deployment may be a more relevant numerical representation of relative deployability. Either representation yields a ratio scale quantification.

f. LETHALITY/SURVIVABILITY. The dimensions of force lethality and survivability are treated simultaneously in this section due to their complementary interaction. It is believed that residual lethality at any time in combat is directly related to the survivability characteristics of the combat systems in the force. While lethality is a measure of a force's potential to inflict casualties and damage to elements of an enemy force, survivability characterizes the force's ability to withstand effects of combat and conduct future combat operations. Lethality, treated alone, may lead to conclusions which create a force with severely limited utility across the spectrum of potential combat environments.

(1) Lethality measurements in recent studies (Ref. 7) have attempted to measure the expected damage which could be inflicted on an enemy force using performance characteristics of lethal systems in the force. Frequently used performance characteristics employed in static analysis are fractional damage, rates of fire and kill probabilities. Aggregation of individual system lethal potentials against types of enemy targets provide a multi-dimensional description of potential force lethality. In the instance (rare) that the preponderance of enemy combatants can be reduced to a single target category, the relevant measure of force lethality is a single value. This value would reflect the total number of expected kills of a type target which the force could potentially achieve in an engagement of a specified duration. A useful method of presentation is aggregation of kill potential with respect to range in a two-dimensional graph. However, this approach does not attempt to account for reduction of lethality due to combat losses in the friendly force. For forces with similar survivability characteristics, however, the lethality approach may be adequate.

(2) Frequently, force survivability is measured by comparing alternative force responses to a common form of enemy attack. Ref. 7 documents such an approach. However, there are responsive methods available to execute lethality and survivability analysis in a less stylized approach which yield single value results for comparison of force alternatives.

(3) The specific method proposed for implementation employs the Counterforce Potentials Model developed by System Planning Corporation (SPC). This deterministic model is currently operated and maintained by analysts in OSD. The model provides a measure of lethality and survivability for alternative force designs engaged against a common threat. As a result of simulated counterbattery fires, countermaneuver fires and direct fire combat, killer-victim scoreboards are generated. Using the starting values and the K-V scoreboards, an eigenvalue method is used to solve for the relative values of weapon systems in the force. From this, a counterforce potential (CFP) can be generated for each alternative force. This CFP becomes a basis for comparison of alternative force designs in the dimensions of lethality and vulnerability.

(4) Reference 8 provides documentation on the CFP model. Several adjustments have been identified at this point which may improve the quality of the model as a tool in FDAD.

(a) Precision Guided Munitions (PGM) do not appear to be explicitly modeled in the current version. Employment of PGM's could be included in the countermaneuver exchange by reducing fractional allocation of fires or by introducing selected indirect fire systems as a separate entry with PGM as its only munition. Current modeling of PGM in DIME may provide mechanics for achieving this modeling adjustment. Fractional allocations of indirect fires may be developed in coordination with Ft. Sill and CACDA, Concepts Development Directorate.

(b) AAH. The Counterforce Potential Model appears to currently model the contributions of helicopters to direct combat lethality. However, documentation does not clearly describe the munitions employed or the "tactics"/engagement discipline executed by aviation assets. It appears that a mechanism exists for adjustment of engagement disciplines.

(c) Air Defense. As with aviation above, CFP appears to model lethal contribution and vulnerability of air defense systems in the force. This aspect of the model also deserves special examination to insure realistic representation. Again, familiarity with modeling of ADA exists as a result of DIME.

(d) The equation employed to compute direct fire kill potentials described below may be refined.

$$K = T_D \int_0^{\infty} N(R) P_K(R) p(R) dR$$

This equation is an expression of direct fire kill potential (K) for each weapon-target pair with variables defined as follows:

$T_D$  - Duration of direct fire period (minutes)  
 $N(R)$  - Rate of fire at range R (shots per minute)  
 $P_K(R)$  - Single shot kill probability at range R  
 $p(R)$  - Density function which describes probability that engagement occurs at range R

$N(R)$  as described in Ref. 8 is a function of firing time at range R. This appears to be a form of sustained rate of fire or trigger pull to trigger pull data. Expected completed firing (ECF) data available in CAORA, TSSD appears to be a better approach to quantification of number of engagements per unit time. ECFs include consideration of weapon firing sequence, target movement and terrain.

The density function,  $p(R)$ , used by OSD to describe engagement distributions was initially an inferred normal distribution. Mr. Hap Miller indicated that he later experimented with skewed distributions with "interesting results". Per Mr. Miller's recommendation, initial coordination has been effected with CPT Snider, TREM concerning investigation of  $p(R)$  using operational data from NTC. CPT Snider is prepared to perform initial data analysis using the CGSC NTC facilities if a decision is made by CAORA to pursue CFP model acquisition. While this investigation might result in data restricted to a single terrain and tactical environment, it may provide valuable insights concerning the engagement process which could be combined with results of CARMONETTE simulations to substantiate the underlying distribution of engagements for principal terrain types.

(5) The proposal to employ the Counterforce Potentials Model is based on examination of several alternative approaches. Key alternatives were Fire Power Potentials and a revised DIME approach. The Fire Power Potentials approach is limited to a measurement of lethality, requires numerous subjective weightings and is not as sensitive to interactions as CFP. "Revised" DIME might well be better than CFP in terms of level of detail but revision would require a significantly greater amount of resources not only in model development but also in model maintenance and application. In some cases however, results from DIME supported studies or higher resolution models may provide K-V results which may be valid for comparative analysis of alternatives. This would be the best case but should not be the sole method for "front-end" analysis.

g. SUSTAINABILITY. A comparison of sustainability of alternative force designs seeks to quantify the requirements for replenishment which are generated by the combat and combat support elements of the force and the capability of the CSS design to satisfy those requirements. For a given level of combat operations, personnel and equipment, an estimate must be generated to identify resource consumption and corresponding replenishment needs of the force.

(1) In the initial stages of the force design process, emphasis must be on an estimate and not detailed computation of individual system consumption factors. Based on message traffic relating to the 1982 HTLD Design Effort, there appears to be reluctance on the part of the LOGCEN to generate such estimates. However, a conversation with Mr. Cameron of the Operations Analysis Directorate, LOGCEN indicated that such estimates are "doable".

(2) It is believed that the LOGCEN is the appropriate agent for analytic support in the dimension of sustainability. The form of the estimate would be a percent of requirements replenishable per operating period for the relevant major CSS functions (personnel, fuel, ammo).

(3) A responsive capability to perform this type of analysis does not appear to exist at present. Data to support such analysis appears to be available at LOGCEN. It is recommended that FDD, CACDA and CAORA establish a program with LOGCEN to develop and maintain a "front-end" sustainability analysis capability. The program would not only provide for model development but also would provide for procedures to specify information required from CACDA and CAORA to execute the model.

(4) The analytic approach proposed above for sustainability attempts to characterize the strain or risk involved with a given CSS structure supporting a specified force. It provides an indicator of the "full-up" capability of the force to conduct extended operations without significant reduction of combat potential due to CSS shortfalls. The premise underlying this approach is that CSS functions are primarily relevant to force effectiveness to the extent that they do not become the binding constraint to combat potential of the force.

h. TACTICAL MOBILITY. A comparison of tactical mobility of force design alternatives seeks to quantify the ability of the force to reposition all or part of the combat elements of the force in a tactical environment. Tactical mobility should be examined in the context of a specific scenario to develop a relevant basis for comparison across alternative force designs.

(1) The technique proposed is to generate a common tactical repositioning requirement for all alternatives to preempt a similar enemy threat. The quantification of tactical mobility would be expressed in terms of the estimated time required to reposition a comparable portion of each alternative force. The time would be measured from decision point to relocate a combined arms team to time units are repositioned. This approach seeks to account for delays which may be imposed due to requirements for non-organic transportation assets, effects of terrain and operational concepts for each alternative force.



(2) It is believed that the dimension of tactical mobility is relevant only in the context of a specific scenario. By establishing a common repositioning requirement across force alternatives in a specific scenario, a valid comparison of tactical mobility may be developed.

i. C<sup>3</sup>I. The comparison of the C<sup>3</sup>I capabilities of alternative force designs is an attempt to quantify the relative ability of forces to develop an accurate perception of the battlefield, to direct action and to control execution of directives. The force C<sup>2</sup> process is believed to be dependent on the information cycle. An initial evaluation of force C<sup>3</sup>I capability may be related to the force's ability to develop an "accurate" perception of the battlefield over time. Sensing agents (radar, recon units etc.) collect and transmit data about enemy elements on the battlefield. The data is collected and correlated by the intelligence subsystem of the force to generate a picture of the enemy. Simultaneously, friendly units report on their own status. Friendly and enemy intelligence create a perception of the battlefield. Repeated sensing may be required to reduce discrepancies and inaccuracies in the perception vs ground truth.

(1) A "front-end" C<sup>3</sup>I analysis tool does not appear to exist at this time. A review or comparative estimate of information collection, communication, and fusion capabilities for alternative force designs may be feasible. This review may result in identification of significant differences in capability of alternative force designs for execution of a common mission against a common threat.

(2) The C<sup>3</sup>I dimension of alternative force design analysis requires additional research and methodology development. However, it does not appear that attempts to tie C<sup>3</sup>I to battle outcomes are feasible in the context of "front-end" analysis.

j. PRESENTATION OF RESULTS. The preceding sections have presented general methodologies to quantify each alternative force design in the dimensions of strategic deployability, lethality/survivability, sustainability, tactical mobility and C<sup>3</sup>I. The results may be tabulated in a matrix with rows corresponding to specific alternatives and columns corresponding to dimensions of comparison. An example of the matrix is presented in Appendix C which also presents a mathematical technique to develop order preference of alternatives. The matrix of values may be used to generate graphics to present comparisons in a briefing or report. A single graph presents a comparison of each alternative in a single dimension. The AOE Briefing (Ref. 3) presents an example of alternative comparison in the dimension of deployability. Similar graphics may be presented for each dimension of comparison.

(1) Examination of the matrix for dominance may reveal clearly inferior alternatives. Establishment of minimum acceptability standards for each dimension may also aid in identifying alternatives which are "weak" in one or more areas. These commonly accepted techniques assist to reduce the complexity of choice by identifying clearly dominant and inferior alternatives.

(2) A refined approach which generates a preference ranking of alternatives is described in Appendix C. If this technique is employed, users must be aware of the strengths and limitations described in Reference 10.

## 6. CONCLUSIONS AND RECOMMENDATIONS.

a. CONCLUSIONS. The preceding chapters have specified the "front-end" force design process executed by FDD, CACDA and identified steps in the process which may require analytic support. General methodologies have been proposed to provide analytic support in a responsive form. It appears that the theory/methodology and tools currently available to FDAD, SAD, CAORA are inadequate to perform "front-end" analysis. CAORA should at least develop a capability to perform acceptable analysis of alternative force designs based upon the methodology presented in Chapter 5.

b. RECOMMENDATIONS. The following recommendations are provided based on this research project.

(1) Continue deployability analysis in FDD utilizing the AALPS deployability model. Enhance this capability to include ship transport of forces to the tactical theater of operations.

(2) Acquire and enhance the Counterforce Potential Model from OASD(PA&E) to achieve an FDAD capability to perform "front-end" lethality/survivability analysis.

(3) Execute coordination with FDD, CACDA and LOGCEN to achieve a LOGCEN capability to perform "front-end" sustainability analysis.

(4) Execute additional research to develop a capability for "front-end" analysis of force C<sup>3</sup>I and tactical mobility.

5 April 1984

MEMORANDUM FOR MAJ Jacobs

SUBJECT: FDAD Research Directive: Analytic Support of the Force Design Process

1. Purpose. To examine the Force Design Process executed by the Force Design Directorate, CACDA to identify specific steps in the process which require analytic support resources from FDAD. For each identified requirement, develop a methodology and specific analytic tools to perform appropriate analysis. This examination is necessitated by the significant reduction in the time span of recent design efforts (ID Light Study - Aug-Oct 83). Methodologies and tools developed as a result of this research effort will be employed in future force design efforts. This is a Category 3 (Operations and Force Structure) research activity.

## 2. References.

- a. TRADOC PAM 71-3, 1 Jun 77.
- b. IP 1-80, Apr 80. RAPID.
- c. AALPS Reference Manual.
- d. JAYCOR TR 2302-83. Weapons Effectiveness Methodology.
- e. CAA-IP-73-7. Firepower Potential Methodology.
- f. CAA-D-80-3. CEN V Technical Description.
- g. CAORA/TR-5/83. DAME Procedures.
- h. SPC Report 856. Counterforce Potentials.
- i. USACDC Pam 71-1. MOE's.
- j. CACDA Division 86 Final Report. Oct 81.
- k. CAA Report: Measuring and Reporting Improvements in Army Capabilities, Sep 83.

3. Study Sponsor. FDAD, SAD, CAORA. MAJ Resnick. (AV) 552-3595/5481.

4. Study Agency. FDAD, SAD, CAORA.

SUBJECT: FDAD Research Directive: Analytic Support of the Force Design Process.

5. Literature Search.

- a. FDD, CACDA. (ATZL-CAF) (AV) 552-4832.
- b. CAA. (CSCA-FO) (AV) 295-1105.
- c. TRASANA. (ATOR-TD) (AV) 258-3136.
- d. DCSCD, TRADOC. (ATCD-A) (AV) 680-3004.
- e. ODCSOPS, DA (DAMO-RQS) (AV) 225-9570.

6. Study Monitor. MAJ Resnick.

7. Terms of Reference.

a. Problem. Recent force design actions executed by FDD, CACDA have been performed in a much shorter time horizon than previous actions. The time span has been characteristically less than eight weeks from receipt of tasking to TRADOC decision briefing. Current methods employed by FDAD have not been adequate to respond to the short term analytic needs of FDD, CACDA.

b. Objectives. In an attempt to provide more responsive analytic support to FDD, CACDA, the following objectives are established for this research effort:

(1) Specify the "shortened time-horizon" Force Design Process.

(2) Identify specific steps in the process which may require analytic support.

(3) For each identified step requiring analytic support, specify the nature of the analytic support required.

(4) For each identified step requiring analytic support, develop an appropriate methodology to perform analysis consistent with the design process time constraint, FDD requirements and available analytic tools.

(5) Decompose each analytic methodology into a specific technique which utilizes a data base and math model to generate appropriate outputs for analysis and presentation of results. This objective implies judicious selection of MOEs and meaningful presentation of results.

(6) Present techniques and gain acceptance by FDD, CACDA representatives for employment in future studies.

c. Scope. Primary focus is on design of Brigade and Division Level Forces.

SUBJECT: FDAD Research Directive: Analytic Support of the Force Design Process.

- d. Time Frame. N/A.
- e. Limits. N/A.
- f. Assumptions. N/A.
- g. Essential elements of analysis. N/A.

h. Constraints. This is a research effort initiated internally by FDAD. Action office will exercise appropriate discretion when seeking information or assistance from other activities or agencies.

- i. Alternatives. N/A.
- j. Operational Concept. N/A.
- k. Mission Profiles. N/A.
- l. HOE. N/A.
- m. Methodology. N/A.
- n. Related Studies. To be identified as part of literature search.

8. Environment/threat guidance. As much as possible methodologies will be developed which are not restricted to a specific environment on threat but are responsive to current principal environments and threats used in doctrinal studies.

9. Support and Resource Requirements: N/A.

10. Administration.

- a. Study title. Analytic Support of the CACDA Force Design Process.
- b. Study schedule. Per Enclosure 1.

ALLAN M. RESNICK  
MAJ, FA  
Ch, FDAD

APPENDIX B  
LIST OF REFERENCES

1. US Army Combined Arms Combat Development Activity, Division 86 Final Report. Fort Leavenworth: October 1981.
2. , Army of Excellence final Report (Draft). Fort Leavenworth: April 1984.
3. US Army Training and Doctrine Command, Army of Excellence. Briefing. Fort Monroe: November 1983.
4. Tiede, Roland V. On the Analysis of Ground Combat. Manhattan, KS: Military Affairs/Aerospace Historian Publishing, 1978.
5. US Army Combined Arms Combat Developments Activity. Technical Report 4-78: CACDA Ground Combat Model. Fort Leavenworth: April 1978.
6. US Army Concepts Analysis Agency. Technical Paper 73-7: Firepower potential Methodology Review. Bethesda, MD: 31 December 1973.
7. US Army Combined Arms Combat Development Activity. (C) Technical Report 4-80: Screening Exercises in Support of ID-86 Study (U) CONFIDENTIAL. Fort Leavenworth: 1980.
8. System Planning Corporation. SPC Final Report 866: Counterforce Potentials: Revised User's Manual. Arlington, VA: December 1982.
9. Research Analysis Corporation. Technical Paper 268: Analysis of Fundamental Relations in Army Mobility Systems. McLean, VA: 1968.
10. Hwang, Ching-Lai; Yoon, Kwangsun. Multiple Attribute Decision Making. New York: Springer-Verlay, 1981.

# APPENDIX C TECHNIQUE FOR ORDER PREFERENCE OF ALTERNATIVES

C-1. PURPOSE. This appendix presents a mathematical technique to obtain an order preference of force design alternatives based upon the quantification of each force's capability in the manner described in Section 5. A more detailed explanation of the methodology presented in this appendix is available in Reference 10, Multiple Attribute Decision Making.

C-2. PROCEDURE. The technique presented in this section provides a mathematical technique to reduce the two-dimensional matrix of alternatives and corresponding attribute values to a vector which orders the preferences of alternatives. The technique mathematically compares each alternative to the ideal solution.

a. The matrix presented below reflects the values obtained by analysis of each alternative in the dimensions of deployability, lethality/survivability, sustainability, tactical mobility and C3I. To achieve consistency, (smaller values imply preferred solution) lethality/survivability values must be inverted while sustainability percentages should reflect that portion of force requirements which are not satisfied by the CSS system.

b. An example of the alternatives attributes matrix appears below:

	Lethality/				
	Deploy	Survivability	Sustain	MOB	C <sup>3</sup> I
A1	$x_{11}$	$x_{12}$	$x_{13}$	$x_{14}$	$x_{15}$
A2	$x_{21}$	$x_{22}$	$x_{23}$	$x_{24}$	$x_{25}$
.					
.					
.					
A <sub>N</sub>	$x_{n1}$	$x_{n2}$	$x_{n3}$	$x_{n4}$	$x_{n5}$

c. Normalize attributes as follows:

$$r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^n x_{ij}^2}$$

d. This yields the matrix R (nx5) which consists of the  $r_{ij}$  normalized attributes.

e. If weighting of attributes is desired then product each column of R by the appropriate weight  $W_j$ ,  $i = 1$  to 5 to obtain the weighted value matrix V consisting of values  $v_{ij}$ . Weights ( $w_j$ ) should be normalized to sum to 1.

f. Determine ideal and negative ideal solutions ( $A^*$  and  $A^-$ , respectively).

$$A^* = v_1^*, v_2^*, \dots, v_5^*$$

where  $v_j^*$  is the smallest value in the appropriate column.

$$A^- = v_1^-, v_2^-, \dots, v_5^-$$

where  $v_j^-$  is the largest value in the appropriate column.

g. Calculate the separation measures for each alternative.  $S_i^*$  is separation from the ideal solution while  $S_i^-$  is separation from the negative ideal solution.

$$S_i^* = \sqrt{\sum_{j=1}^5 (v_{ij} - v_j^*)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^5 (v_{ij} - v_j^-)^2}$$

h. Calculate relative closeness of each alternative to the ideal solution.

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-} \quad 0 < C_i^* < 1 \quad i = 1, 2, \dots, 5$$

NOTE:  $C_j^* = 1$  if  $A_j = A^*$  and  $C_j^* = 0$  if  $A_j = A^-$

i. Rank the preference order of alternatives. An alternative  $A_j$  is closer to  $A^*$  as  $C_j^*$  approaches 1.



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